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Editorial

Framework and perspectives of industrial lignocellulosic ethanol deployment: Introduction to the 1st International Conference on Lignocellulosic Ethanol

1. Biofuels policy in the European Union

Biomass is currently the only large scale renewable energy source that can produce competitively priced fuels for transport. It is possible to obtain fuels from biomass that have very similar properties to those of conventional fossil fuels, minimising the need to adapt end-use technologies. If properly managed in a sustainable way, biofuels have the potential to significantly contribute to the global transport fuel supply.

In 2007, the European Union set its climate and energy targets for 2020: to achieve a 20% share of renewable energy, a 20% improvement in energy efficiency and a 20% reduction of greenhouse gas (GHG) emissions by 2020 [1]. Furthermore, within the 20% renewable energy target, there is more specific target for 10% contribution of renewable fuels in transport. Sustainable bioenergy production can contribute to all three of these targets. Within the Renewable Energy Directive (RED), the European Union adopted sustainability criteria and counting rules for biofuels to be used in its market. Sustainability criteria for biofuels and bioliquids are defined at Article 17 (pp. L140/36–L140/38) of RED [1]. The main sustainability criteria laid down in the Directive are summarised below:

- The GHG-emission savings from the use of biofuels and bioliquids shall be at least 35% (rising to 50% in 2017 and 60% in 2018 for new installations). “Bioliquids” are defined at Article 2.h of RED [1] (pp. L140/2) as “liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass”.
- Biofuels and bioliquids shall not be made from raw material obtained from land with high biodiversity value.
- Biofuels and bioliquids shall not be made from raw material obtained from land with high carbon stock.

The calculations of the GHG impact of biofuels and bioliquids were specified in Article 19. Aiming to facilitate the deployment of second-generation biofuels, RED stipulates that the contribution to the national target for the use of energy from renewable sources made by biofuels produced from wastes, residues, non-food cellulosic material, and

lignocellulosic material shall be considered to be twice that made by other biofuels. Finally, every Member State shall submit a report to the Commission biennially on progress in the promotion and use of energy from renewable sources (included biofuels and bioliquids).

At the end of 2007, the Commission proposed the Strategic Energy Technology Plan (SET-Plan) [2]. A more strategic approach to technology development and deployment is necessary to ensure the achievement of political objectives. By the end of 2009, the primary practical instruments and budgetary implications were further developed in the Commission Communication on Investing into Low Carbon Technologies [3]. This was accompanied by “A Technology Roadmap” presenting the fundamental roadmaps for wind energy, solar energy, the electricity grid, bioenergy, carbon capture and storage, nuclear and the Smart Cities Initiative, which serve as a basis for strategic planning and decision making [4].

In order to pull together the existing expertise in the EU, the European Commission created the Biofuels Research Advisory Council (BRAC) in 2005, which consists of leading experts in the field and Commission representatives [5]. It charged this think tank with producing a visionary document for biofuel deployment in the EU. The BRAC vision foresees up to one-fourth of the EU’s transport fuel being met by clean and CO₂-efficient biofuels by 2030 [6]. The BRAC provided the foundations of the European Biofuels Technology Platform (EBTP), which was established in 2006 to contribute to the development of cost-competitive, world-class biofuels technologies, and to accelerate the deployment of sustainable biofuels in the EU through a process of guidance, prioritisation and the promotion of research, development and demonstration activities (R&D&D). The EBTP consists of leading experts from all technology areas, biofuel producers, oil companies, the automotive industry, other market players, and NGOs. The EBTP published its Strategic Research Agenda in January 2008 [6] and a revised version in July 2010 [7]. The Strategic Research Agenda of 2008 identified the main research and demonstration needs for conversion technologies, resource production and supply, as well as

environmental and sustainability issues. The 2010 revision placed a greater focus on the actions necessary for launching the European Industrial Bioenergy Initiative.

2. The European Industrial Bioenergy Initiative

The EIBI is characterised by very innovative technologies and high-risk investments in comparison to all other renewable energy industrial initiatives which aim to improve existing technologies that already have a place in the market and to further facilitate their penetration. The EIBI, on the other hand, aims to bring new technologies onto the market for the first time. The focus is primarily on second-generation bio-fuels production from lignocellulosic biomass, advanced CHP technologies and novel concepts of producing biomass intermediate products.

The EIBI is based on seven value chains, which are summarised in Table 1. In addition to the seven value chains, two horizontal actions are also addressed that are critical for a successful deployment of bioenergy technologies in the EU market. These address the resource availability in the EU and beyond, as well as social acceptance. These two horizontal actions will be addressed directly by the 7th Framework Programme (FP7) and other EU programmes such as the Intelligent Energy for Europe Programme. The Intelligent Energy – Europe programme is the EU's tool for funding action to improve these conditions and move towards a more energy intelligent Europe [8]. With Euro 730 million funds available between 2007 and 2013, the Intelligent Energy – Europe (IEE) programme helps deliver on the ambitious targets that the EU has set for itself to sustain the competitiveness of its economy while fighting climate change. It does so by supporting concrete projects and real people doing real things.

The EIBI will address only large-scale industry-led projects that are based on innovative technologies and processes or

novel integration of known technologies and processes to be established at the appropriate scale for demonstration plants and first of-the-kind, “Demonstration plants” are considered the last non-economic step to demonstrate the technical, environmental and economical performance and reliability of all critical steps in a value chain so that the first commercial unit can be designed and the technical performance guaranteed from the outcome of the demo unit; “first of-a-kind-plants” are the first commercial units of value chains operating at an economically viable scale.

At least one section of the value chain or the integration of sections of the considered value chains should not have been deployed on a demonstration/commercial scale before.

Similar policy and energy technology initiatives are being undertaken in parallel in several other countries such as the USA, Brazil and elsewhere.

3. Ethanol from lignocellulosics

Over the last decade energy research on biofuels has focused mainly on the so-called 2nd generation biofuels which are produced by processing lignocellulosic biomass, residues and wastes streams to liquid or gaseous biofuels in contrast to the 1st generation biofuels which are produced by processing, sugars, starches and vegetable oils; all originating from the food chain. There are several thermochemical and biological processes that can treat lignocellulosic biomass, however, amongst these the conversion technology that is progressed the fastest and now is in the early market deployment stage is lignocellulosic ethanol which is addressed under the 5th value chain, “Ethanol and higher alcohols from lignocellulosic feedstock through chemical and biological processes”. Lignocellulosic ethanol has achieved significant progress the last few years and it is considered the value chain closer to commercial deployment. Breakthrough research has been undertaken initially in the US especially in reducing the cost of enzymes where European based companies played a leading role. The last 5 years several demonstrations projects were announced and built and there is a certainty in the industry addressing this sector that the costs can be reduced further making ethanol from lignocellulosics competitive to ethanol from sugars and starches in the short term.

Under the 7th Framework Programme for Research and Technological Development [9] four large scale demonstration projects were supported in 2009 by the European Commission while at present two flagship projects have been approved for support and are now under negotiations with the industrial partners; see Table 2.

The rapid developments in this sector prompted the Directorate General for Energy of the European Commission to create a forum for discussion and exchange of information amongst the key stakeholders with main emphasis on the industry developing the various stages of this value chain. This took the form of an international conference that has been held twice, the first one on 13–15 October 2010 in Copenhagen and the second one on 11–13 October 2011 in Verona. The conferences are organised in close cooperation with the coordinators of the EC funded FP7 contracts (see Table 2) and include a visit to the demonstration plant of the

Table 1 – EIBI bioenergy value chains and horizontal actions [4].

Generic value chains

Thermochemical pathways (TP)

- 1: Synthetic liquid fuels and/or hydrocarbons (e.g. petrol, naphtha, kerosene or diesel fuel) through gasification
- 2: Bio-methane and other bio-synthetic gaseous fuels through gasification
- 3: High efficiency heat & power generation through thermochemical conversion
- 4: Intermediate bioenergy carriers through techniques such as pyrolysis and torrefaction

Biochemical pathways (BP)

- 5: Ethanol and higher alcohols from lignocellulosic feedstock through chemical and biological processes
- 6: Hydrocarbons (e.g. diesel and jet fuel) through biological and/or chemical synthesis from biomass containing carbohydrates
- 7: Bioenergy carriers produced by microorganisms (algae, bacteria) from CO₂ and sunlight

Horizontal actions (HA)

- 8: Resource availability and spatial planning
- 9: Public acceptance

Table 2 – Ethanol from lignocellulosic projects supported under FP7.

Contract Acronym	Leading industry	EC Support € M	Biomass	Production Capacity t y ⁻¹	Year of FP7 Call	Status
BIOLYFE	Chemtex Italia	8.6	Various	40,000	2008	On
FIBREETOH	UPM	8.6	Recycled fibre	20,000	2008	On
KACELLE	Dong Energy/Inbicon	9.1	Straw	20,000	2008	On
LED	Abengoa	8.6	Corn residues	50,000	2008	On
SUNLIQUID	Süd-Chemie	±19.0	Straw	60,000	2012	UN
COMETHA	Chemtex Italia	±18.0	Arundo Donax + various	80,000	2012	UN
		Total = ±71.9				
Note: On = ongoing. UN = Under Negotiations, EC support may vary from the one quoted in the table.						

coordinator. Thus in 2010 the conference participants visited the Dong Energy/Inbicon demonstration plant at Kalundborg, Denmark while in 2011 they visited the Mossi&Ghisolfi/Chemtex Italia plant at Crescentino, Italy while it was under construction. The third International Conference on Lignocellulosic Ethanol will be held on 3–5 April 2013 in Madrid. During the conference the participants will visit the Abengoa Bioenergy plant at Salamanca, Spain.

Institutions from Brazil and the United States closely cooperated in the organisation of these conferences.

This Special Issue of Biomass and Bioenergy contains 7 articles from some of the industrial speakers who participated in the programme of the 1st International Conference on Lignocellulosic Ethanol. These give an excellent overview of the progress achieved in the sector and show that indeed the commercialisation of lignocellulosic ethanol has actually already started. There is widespread confidence in the industry that commercial plants will be operating by 2015 and that the prospects for a competitive supply of sustainably produced ethanol is within sight.

4. Brief introduction to the 7 articles of the special issue

The first article by Liisa Viikari et al. provides a general overview of the recent developments in the sector with attention to the enzymatic hydrolysis process and the costs of ethanol production. It reviews the major bottlenecks in the conversion process as well as highlights recent approaches to overcome these problems. Authors observe that significant achievements have been obtained since the '70s, and that the cost of enzymatic hydrolysis significantly decreased: based on that, they estimate that enzymatic processing will no longer be the bottleneck for commercialization of cellulosic ethanol within this decade.

The following two articles examine carefully the various pretreatment processes for the lignocellulosic feedstocks that aim to separating the main biomass components (cellulose, hemicellulose and lignin) so that they are more accessible to enzymes and other downstream processing. David Chiaromonti et al. review the main options available in pretreatment, selecting auto-hydrolysis and steam explosion for more in depth discussion. A new process using only water and

steam as reacting media was developed, and experimentally tested. The results were compared favourably to those achieved by auto-hydrolysis and steam explosion and provided the basis for further industrial development by M&G/Chemtex at industrial demonstration scale. Mats Gable and Guido Zacchi carried out a thorough analysis of several pretreatment methods providing guidance on how assessment should be performed to reach optimal conditions. They conclude by noting that in spite of the progress achieved it is necessary to reassess the various pretreatment methods at more-industrial like conditions considering the whole integrated process taking into account the influence on all process steps.

Gudbrand Rødsrud et al. describe the long-term experience of Borregaard in Sarpsborg Norway being one of the most advanced biorefineries in operation today with more than 40 years' experience of running a commercial biorefinery. Based on Borregaard's experience and presence in many markets, new strategies for converting lignocellulosic biomass to biochemicals and biofuels in a sustainable and profitable way is presented. Both experience from the long history of running a biorefinery as well as the main development routes for future new bioproducts is analysed and discussed. The key message from the article is the necessity for continuous development and innovation in the operations and value chains of the biorefinery.

The following two papers present the developments from two projects supported by EC-FP7, KACELLE and FibreEtOH (see Table 2). Jan Larsen et al. describe the developments at the Inbicon biorefinery at the port of Kalundborg where wheat straw is converted to lignocellulosic ethanol, lignin pellets and C5 molasses. The facility went into the production phase by the end of 2010 and Statoil is distributing the lignocellulosic ethanol in 100 filling stations in Denmark. The paper concludes by stressing that while lignocellulosic ethanol is a reality, further policy and market incentives are needed before investors will construct the first full scale commercial plants. Katariina Nyman et al. describe the FibreEtOH concept which was developed to tackle the production of ethanol from waste streams and residues. The process is based on waste fibre fractionated from solid recovered fuel, pulp and paper mill sludge. Such resources can provide all-year round supply of biomass with high hexose content and acceptable ash content. The process is being scaled up to demonstration level from a pilot plant where fractionation of solid recover fuel,

continuous liquefaction and simultaneous saccharification and fermentation as well as biogas production from the fermented residue were studied.

André Corrêa do Lago et al. describe strategies in Brazil to produce lignocellulosic ethanol from bagasse. With a supply of 84 million tonne of bagasse at no cost and 42 million tonne of trash lignocellulosic ethanol, integrated with sugarcane ethanol in biorefinery concept, can be produced cheaply. The integration of first and second generation technologies is seen as crucial to keep production costs low and benefit from sharing common facilities. Based on consolidated institutional and political conditions, a growing economy, and a long experience in the field of the fuel ethanol chain, Brazil is emerging in the international context as a key actor in the process of creating an international market for biofuels.

5. Conclusions

Overall the 7 articles and the other presentations given during the conference provide a solid basis for technical reliability and economic viability of the sector. Large scale facilities are being built across the planet and the industry is moving forward with concrete steps and significant investments. However, the policy and the market initiatives are not yet sufficiently developed to give confidence to investors for long term investments. Policy stability is crucial for the sector of second-generation biofuels in general and lignocellulosic ethanol in particular. Another area of key concern to the industry and eventual investors is the lack of adequate financial mechanisms to support the construction of the large scale demonstration plants and first-of-a-kind commercial plants. The investment for the former is in the range of Euro 40–120 million while it raises in the range of Euro 100–250 million for the later. It is clear that the industry cannot carry such investments on its own. Measures such as state-loan guarantees and off-take agreements have been discussed and tried in some countries but a mixture of incentives may provide the most reliable basis for providing certainty to investors.

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